Office of the Under Secretary of Defense for Research and Engineering
Defense Research and Engineering for Research and Technology (DDRE(RT))
C5ISREW – Quantum Science Topics
22.1 Small Business Innovation Research (SBIR)
Direct to Phase II (DP2) Proposal Submission Instructions

INTRODUCTION

The Office of the Undersecretary of Defense, Research and Engineering (OUSD(R&E)) Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, Reconnaissance and Electronic Warfare (C5ISREW) Office in partnership with the Director of Defense Research & Engineering for Modernization (DDRE(M)) Quantum Science Office seeks to advance scientific discoveries in alignment with the USD(R&E) Quantum Science Roadmap and provide a mechanism to further scientific development, maturation, and commercialization of quantum science technologies. The C5ISREW SBIR program aims to stimulate technological innovation, strengthen the role of small business in meeting DoD research and development needs, foster and encourage participation by minority and disadvantaged persons in technological innovation, and increase the commercial application of DoD-supported research or research and development results. **The C5ISREW SBIR program solicits approaches that combine high-risk with potential for high-reward to address scientific challenges described in the topics below.**

Proposers responding to a topic in this BAA must follow all general instructions provided in the Department of Defense (DoD) SBIR Program BAA. C5ISREW requirements in addition to or deviating from the DoD Program BAA are provided in the instructions below.

Specific questions pertaining to the administration of the C5ISREW SBIR/STTR Program and these proposal preparation instructions should be directed to: Dr. Karl Dahlhauser, karl.j.dahlhauser.civ@mail.mil.

DIRECT TO PHASE II (DP2) PROPOSAL GUIDELINES

15 U.S.C. §638 (cc), as amended by NDAA FY2012, Sec. 5106, and further amended by NDAA FY2019, Sec. 854, PILOT TO ALLOW PHASE FLEXIBILITY, allows DoD to make a SBIR Phase II award to a small business concern with respect to a project, without regard to whether the small business concern was provided an award under Phase I of the SBIR program with respect to such project. C5ISREW will conduct a "Direct to Phase II" implementation of this authority for select topics under this BAA, as specified in these instructions.

Each eligible topic requires that proposers provide documentation to demonstrate feasibility described in the Phase I section of the topic has been met. **Feasibility documentation cannot be based upon or logically extend from any prior or ongoing federally funded SBIR or STTR work.** Work submitted within the feasibility documentation must have been substantially performed by the proposer and/or the PI. If technology in the feasibility documentation is subject to Intellectual Property (IP), the proposer must either own the IP, or must have obtained license rights to such technology prior to proposal submission, to enable it and its subcontractors to legally carry out the proposed work.

If the proposer fails to demonstrate technical merit and feasibility equivalent to the Phase I level as described in the associated topic, the related Phase II proposal will not be accepted or evaluated.

The Defense SBIR/STTR Innovation Portal (DSIP) is the official portal for DoD SBIR/STTR proposal submission. Proposers are required to submit proposals via DSIP; proposals submitted by any other means will be disregarded. Detailed instructions regarding registration and proposal submission via DSIP are provided in the DoD SBIR/STTR Program BAA.

A complete proposal consists of the following:
Volume 1: Proposal Cover Sheet
Volume 2: Technical Volume
Volume 3: Cost Volume
Volume 4: Company Commercialization Report
Volume 5: Supporting Documents

a. Contractor Certification Regarding Provision of Prohibition on Contracting for Certain Telecommunications and Video Surveillance Services or Equipment (DoD Program BAA Attachment 1)
b. Foreign Ownership or Control Disclosure (Proposers must review DoD Program BAA Attachment 2: Foreign Ownership or Control Disclosure to determine applicability.)
c. Other supporting documentation (Refer to topic description for additional Volume 5 requirements)

Volume 6: Fraud, Waste and Abuse Training

Follow the instructions and guidance provided in section 5.3 of the DoD Program BAA for completing these proposal volumes.

Technical Volume (Volume 2)
The technical volume for DP2 proposals consist of two parts:

- **PART ONE: Feasibility Documentation**: Provide documentation to substantiate that the scientific and technical merit and feasibility described in the Phase I section of the topic has been met and describes the potential commercial applications. Documentation should include all relevant information including, but not limited to: technical reports, test data, prototype designs/models, and performance goals/results. **Maximum page length for feasibility documentation is 10 pages**. If you have references, include a reference list or works cited list as the last page of the feasibility documentation. This will count towards the page limit. Work submitted within the feasibility documentation must have been substantially performed by the proposer and/or the PI. If technology in the feasibility documentation is subject to Intellectual Property (IP), the proposer must either own the IP, or must have obtained license rights to such technology prior to proposal submission, to enable it and its subcontractors to legally carry out the proposed work. Documentation of IP ownership or license rights shall be included in the Technical Volume of the proposal. DO NOT INCLUDE marketing material. Marketing material will NOT be evaluated.
- **PART TWO: Technical Proposal:** Content of the Technical Volume should cover the items listed in section 5.3.c. of the DoD SBIR Program BAA. **The maximum page length for the technical proposal is 15 pages.**

Cost Volume (Volume 3)
For topic OSD221-D05, the Base amount must not exceed $1,000,000 for a 12-month period of performance and the Option amount must not exceed $700,000 for a 12-month period of performance.

For topic OSD221-D08, the Base amount must not exceed $900,000 for an 18-month period of performance and the Option amount must not exceed $800,000 for an 18-month period of performance.

Costs for the Base and Option must be separated and clearly identified on the Proposal Cover Sheet (Volume 1) and in Volume 3.

Company Commercialization Report (CCR) (Volume 4)
Completion of the CCR as Volume 4 of the proposal submission in DSIP is required. Please refer to the DoD SBIR/STTR Program BAA for full details on this requirement. Information contained in the CCR will be considered by C5ISREW during proposal evaluations.

Supporting Documents (Volume 5)
Supporting documents will be accepted/required as indicated in each topic.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)
The DDRE(RT) C5ISREW Office will not participate in the Technical and Business Assistance.

EVALUATION AND SELECTION
All proposals will be evaluated in accordance with the evaluation criteria listed in the DoD SBIR/STTR Program BAA.

Proposing firms will be notified of selection or non-selection status for a Phase I award within 90 days of the closing date of the BAA.

Refer to the DoD SBIR/STTR Program BAA for procedures to protest the Announcement.
As further prescribed in FAR 33.106(b), FAR 52.233-3, Protests after Award should be submitted to: Dr. Karl Dahlhauser, karl.j.dahlhauser.civ@mail.mil.

C5ISREW SBIR 22.1 Direct to Phase II Topic Index

OSD221-D05	Networked quantum sensor for geolocation of anomalous underground ferrous sources
OSD221-D08	Open environment nuclear quadrupole magnetic resonance detection

OSD221-D05 TITLE: Networked quantum sensor for geolocation of anomalous underground ferrous sources

OUSD (R&E) MODERNIZATION PRIORITY: Quantum Science

TECHNOLOGY AREA(S): Sensors, Electronics and Electronic Warfare

OBJECTIVE: Detect and geo-locate subterranean tunneling activities by using a quantum networked magnetometer.

DESCRIPTION: In challenging environments, the DoD needs the capability to distinguish hidden threats in subsurface environments. These threats manifest as hidden, dynamic, and ferrous materials violating the perimeters of sovereignty. Quantum magnetic sensors have surpassed conventional sensors in demonstrating higher sensitivity and lower SWaP. However, these sensors have yet to convincingly demonstrate a relevant DoD mission in terms of geolocation and detection at a judicious range. The DoD recognizes that one stand-alone sensor is not adequate to detect these anomalies, but rather an array of sensors working in unison is required. Therefore, DoD seeks networked sensors with algorithms and signal-processing techniques demonstrating real-time geolocation, identification, and dynamic tracking of threats. Of particular interest is harbor defense, FOB protection, and border security. This effort is not intended to fund magnetometer development but rather experimental demonstrations that isolate signals of interest from noise to ascertain geolocation from the surface within 10% error underground and/or undersea. Furthermore, limits of range of detection given configuration of an array is of high interest to the DoD. Pathway towards further development to a much bigger network of sensors globally should be addressed at the conclusion of this work.

PHASE I: To qualify for Direct to Phase II, sufficient evidence of a previous externally funded effort that specifically addresses detection of underground activities is needed. Any final reports, findings, publications must be included in the proposal.

PHASE II: In order for this project to be successful, detected signals from tool movement inside a tunnel must be processed and adapted to the inverse propagation model with accurate geo-location. This effort does not repeat sensor development, but rather focuses on algorithm development and system integration to increase the technology readiness level (TRL). To accommodate algorithm development, it is desirable to set up a prototype system at a remote tunnel site for continual collection of data to verify and fine tune the physics model for geo-location. Although the geo-location algorithms worked in previous testing for simple sources with predictable magnetic fields, geo-location of hand tools was not as successful. The Phase II effort should significantly extend the system's ability to detect the use of hand tools in a subterranean environment. We are also looking to find ways to minimize sensor deployment but maximize detection range.

PHASE III DUAL USE APPLICATIONS: If the project is successful, Phase III can be extended to undersea for port surveillance, PBIED detection, and border protection for illegal drug movement underground (between US/Mexico border etc.)

REFERENCES:

1. L. G. Stolarczyka, R. Troublefielda, J. Battis. "Detection of Underground Tunnels with a Synchronized Electromagnetic Wave Gradiometer", Proceedings of SPIE Vol. 5778, doi: 10.1117/12.609623.
2. L. Chen, Y. Feng, P. Wu, W. Zhu and G. Fang, "An Innovative Magnetic Anomaly Detection Algorithm Based on Signal Modulation," in IEEE Transactions on Magnetics, vol. 56, no. 9, pp. 1-9, Sept. 2020, Art no. 6200609, doi: 10.1109/TMAG.2020.3005896.

KEYWORDS: quantum sensor; atomic magnetometer; tunnel detection; networked quantum sensor

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OSD221-D08 TITLE: Open environment nuclear quadrupole magnetic resonance detection

OUSD (R&E) MODERNIZATION PRIORITY: Quantum Science

TECHNOLOGY AREA(S): Sensors, Electronics and Electronic Warfare

OBJECTIVE: Develop a quantum magnetometer that is widely tunable between 100 Hz and 10 MHz to detect and distinguish RF signals with sensitivity near 1 fT/Hz1/2. The sensor system should simple and easily adapted to any system that uses an antenna in this frequency range. The sensor shall also possess the properties necessary to support nuclear quadrupole resonance (NQR) detection in an outdoor open environment.

DESCRIPTION: Quantum magnetic sensing has been continuously advancing performance down below the femtotesla level. Whereas previously applications that utilizes such sensitivity such as magnetoencephalography required shielded environments, now modern quantum magnetic sensors are offering the same sensitivity in the open environment. For various DoD-related missions, there is a need to detect down to 1 fT/rtHz in open environments at a wide range of frequencies below 10 MHz. This requires pushing the limits of even the best magnetic sensors to mitigate noise, be robust to electromagnetic disturbance, and detect faint magnetic fields. The objective of this project is to develop a practical and versatile high-performance radiofrequency quantum magnetometer that can be used in a variety of commercial and defense applications. The sensor system should be specifically but not exclusively engineered to detect weak NQR signals at standoff, which could give significant asymmetric warfighter advantage as well as domestic security.

PHASE I: Previous proposer experience with rf atomic magnetometers of any type can support a Direct to Phase II proposal, including reports and data from proposer's previous sensor prototype operation and/or previous proposer laboratory measurements. Any final reports, findings, publications must be included in the proposal.

PHASE II: The Phase II may include a base program of up to 18 months and an Option program of up to 18 months to develop a prototype quantum antenna.

In the Base program, the project shall develop a versatile and automated atomic rf magnetometer system that is widely tunable from 100 Hz to 10 MHz with sensitivity better than 10 fT/rtHz. The program shall develop fully automated operation, with the user specifying the center frequency and the sensor supplying the signal at that frequency with a >= 1 kHz bandwidth. The outputs shall be both the raw analog signal via coaxial connector and the digitally demodulated signal via a data port such as USB. Multiple sensors must be synchronized and calibrated to achieve common mode rejection ratio (CMRR) > 100. An array of 4 sensors should be constructed and demonstrated measuring an RF tensor field and also demonstrated for common mode interference rejection.

The sensor shall offer two operating modes; the unit shall support continuous wave (CW) operation in the Base program and develop pulsed mode operation in the Option period. In the Option period, the sensor sensitivity shall be improved to 1 fT/rtHz. The sensor hardware shall furthermore be hardened to survive typical NQR excitation pulse without damage. The pulsed mode operation shall rapidly recover operation after electromagnetic disturbance such as a typical NMR or NQR excitation pulse in time to recieve an NMR echo signal. The prototype should be developed as a potential drop-in replacement for a typical NQR coil and offer an appropriate interface for an NMR/NQR spectrometer such as the Tekmag Redstone.

At the end of the program, a final sensor protoype deliverable shall be smaller than 5x5x15 cm^3 and consume less than 10 W power.

PHASE III DUAL USE APPLICATIONS: Describe one or more potential commercial applications, and one or more potential DoD/military applications for the technology that may be pursued by the firm post Phase II. Phase III refers to work that derives from, extends, or completes an effort made under prior SBIR/STTR funding agreements, but is funded by sources other than the SBIR/STTR Program.

There are numerous compelling commercial and defense applications for a tunable RF atomic magnetometer: With the addition of an excitation pulse, the RF magnetometer can detect NMR and NQR signals. The NMR capabilities can enable higher sensitivity for low field magnetic resonance imaging. Measurement of the RF tensor field can enable source tracking and location. Measurement of oilfield NMR can be enhanced by a high performance magnetic sensor. Underwater, underground, and surface-to-cave communications can be uniquely enabled by a portable, ultrasensitive magnetic sensor.

REFERENCES:

1. I. M. Savukov, S. J. Seltzer, M. V. Romalis and K. L. Sauer. "Tunable Atomic Magnetometer for Detection of Radio-Frequency Magnetic Fields." Phys. Rev. Lett. 95, 063004 (2005).
2. I. M. Savukov, S. J. Seltzer, and M. V. Romalis. "Detection of NMR signals with a radio-frequency atomic magnetometer." Journal of Magnetic Resonance. 185, 214 (2007).
3. S.-K. Lee, K. L. Sauer, S. J. Seltzer, O. Alem, and M. V. Romalis. "Subfemtotesla radio-frequency atomic magnetometer for detection of nuclear quadrupole resonance." Appl. Phys. Lett. 89, 214106 (2006).
4. Robert J. Cooper, David W. Prescott, Peter Matz, Karen L. Sauer, Nezih Dural, Mike Romalis, Elizabeth L. Foley, Thomas W. Kornack, Mark Monti, and Jeffrey Okamitsu. "Atomic Magnetometer Multisensor Array for rf Interference Mitigation and Unshielded Detection of Nuclear Quadrupole Resonance." Physical Review Applied 6, 064014 (2016).
5. Orang Alem, "Spin-damping in an ultra-sensitive tunable rf atomic magnetometer" Dissertation, George Mason University (2011).

KEYWORDS: Quantum sensors; magnetic resonance detection; RF, atomic magnetometer, optical magnetometer, NMR, NQR, SLF, ULF, VLF, LF, MF

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